Study on the electrostatic shedding and crushing characteristics of ethanol and diesel droplets

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Abstract: The study of electrostatic shedding and crushing characteristics of droplets is the basis of understanding electrostatic atomization, and the study of its shedding and crushing behavior in electrostatic field is conducted. Micropump drive is used to control the flow rate, electrostatic generation device to form a stable electric field, light lighting and high-speed camera to obtain the dynamic behavior of shedding and crushing process, and use digital image processing technology to extract the process parameters. The results show that: when the capillary tube diameter and flow are unchanged, when the electric field voltage is low, the droplet deviates and falls off, the diesel droplet is smaller than the ethanol; when the electric field voltage is moderate, the droplet is closed or deformed into wave strip; only when the flow rate increases and the electric field voltage is large, the average particle size of ethanol is smaller than diesel, indicating that the electrostatic atomization effect of ethanol with small surface tension is significantly better than that of diesel oil.

Keywords: droplet drop off; droplet breakage; static atomization; liquid fuel

1. Introduction

Liquid fuel can be atomized under the action of machinery, pressure, pneumatic (bubble), ultrasonic, piezoelectric and static electricity. Among them, electrostatic atomization is a process in which liquid overcomes surface tension and breaks into tiny droplets under the action of external electrostatic field, which has been widely used in mass spectrometry analysis, propeller, internal combustion engine and 3D printing [4-7]. According to the Rayleigh guidelines [8], when the amount of droplet charge exceeds a certain limit value, the droplet overcomes the surface tension to breaks. H. And Watanabe et al [9]. This study shows that adjusting the strength of the electric field can effectively control the size and fragmentation range of droplet fragmentation. Although electrostatic atomization is widely used, the mechanism of electrostatic shedding and fragmentation of droplets is not clear [10-11]. For this purpose, we study the shedding and crushing behavior of the ethanol and diesel droplets under electrostatic fields, and reveal the influence of surface tension on the shedding diameter, offset angle, and the average diameter during crushing.

2. Principle of drop shedding and fragmentation

2.1. Analysis of droplet electrostatic drop-off force

The force of charged droplets in the electric field is shown in Figure 1. In the absence of electric field, gravity and surface tension fs Jointly determine its shedding situation, when fg>fs The droplets gradually fall vertically. Balancing the f according to the force g=fs, the diameter of the drop is

$$D=\sqrt[3]{\frac{6d\sigma}{\rho g}} \tag{1}$$

Where d is the capillary tube diameter and σ is the surface tension coefficient / droplet density.

During the applied electric field, the droplet is charged, and its shedding is mainly determined by the surface tension, electric field force and gravity. The electric field force in the horizontal direction causes

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the droplet to produce a certain offset, and the droplet shedding trajectory and the vertical direction form the offset angle. According to the force balance analysis, the offset angle is

$$\theta = \arctan \frac{qU}{\pi d l \sigma} \tag{2}$$

Where 0 is the droplet charge, u is the supply voltage " is the parallel electric field plate spacing.

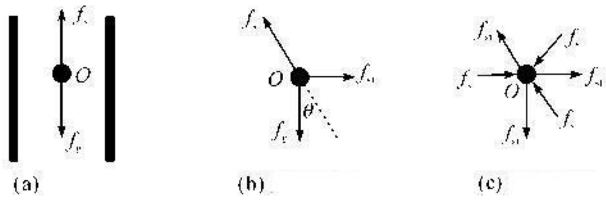

Figure 1 Schematic diagram of the charged droplet force in the electric field

2.2. Broken conditions

On the surface of a droplet with electric power q, the electrostatic force causes the droplet to break and deform, while the surface tension fs to block the droplet fragmentation and deformation. When the surface tension on the droplet surface is less than that of electrostatic force, the droplet loses stability and breaks and deform. According to the Rayleigh limit, the maximum value of the amount charged when the droplet remains stable is

$$q_{\max} = 2\pi \sqrt{2\varepsilon_0 \sigma D_{cr}^3} \tag{3}$$

Where stasis is the vacuum dielectric constant and Ocr is the critical diameter. If the charge exceeds this maximum, the droplet loses stability and causes fragmentation. The maximum density of the charge carried by the droplet is

$$\rho_{\max} = \frac{q_{\max}}{V} = \frac{12\sqrt{2\varepsilon_0 \sigma}}{\sqrt{D_{cr}^3}} \tag{4}$$

Where the volume of a spherical droplet " + blood. The maximum critical diameter of the droplet of [12] can be obtained from Equation (4)

$$D_{cr} = \sqrt{\left(\frac{12\sqrt{2\varepsilon_0 \sigma}}{\rho_{\max}}\right)^3} \tag{5}$$

3. Experimental device

The schematic diagram of the electrostatic shedding and fragmentation of the fuel droplets is shown in Figure 2. The liquid fuel (anhydrous ethanol and 0 # diesel) is put into the syringe respectively, and then the syringe is driven to control the flow through the micropump (WPZS-50F6 of Zhejiang Smith Medical Instrument Co.). The liquid flows through the hose to the capillary, generating droplets at the capillary end. The inner diameter of the capillary is 1.0 mm and the outer diameter is 1.3 mm and placed in the atmosphere at room temperature. High voltage electrostatic generator (Boer high voltage power supply 73030P, adjustable output voltage is 030 kV, and maximum output power is 30 W) is used to control the voltage. High-speed camera (Phantom M-310) collects images to observe the deviation and fragmentation of droplets under the action of electrostatic field. The characteristic information of the electrostatic drop

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and digital image processing of the drop and fragmentation of the system, mainly including the neck diameter, offset angle and the average particle size of the drop under the electric field.

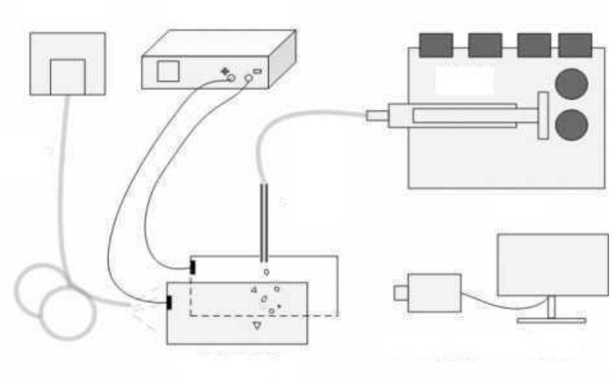

Figure 2 Schematic diagram of the experimental device for droplet electrostatic shedding and fragmentation

4. Results analysis and discussion

4.1. Neck diameter contrast

Both the offset and shedding of ethanol and diesel in the electrostatic field when flow rate of 1.0ml / h and voltage of 3kV are shown in Figure 3, and the curve of the neck diameter change of the droplets during shedding is shown in Figure 4.

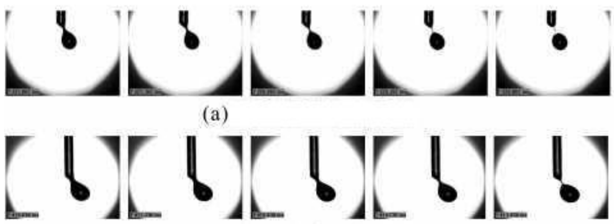

Figure 3 The offset of droplets in the electrostatic field when flow is 1.0 ml / h and voltage is 3 kV

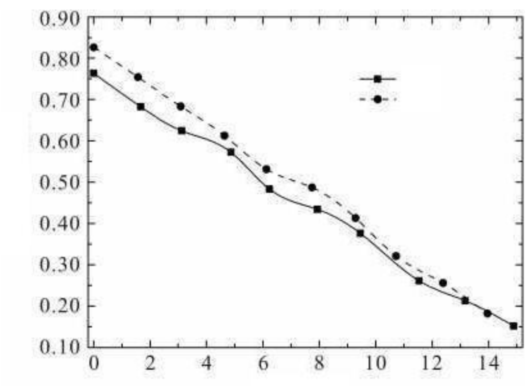

Figure 4 shows the droplet neck diameter change in the electrostatic field with a flow rate of 1.0 ml / h and a voltage of 3 kV

Under the same electric field, the particle size of diesel oil solution is larger than that of ethanol solution. During migration, the neck diameter of diesel oil was greater than that of ethanol at the same time. The particle sizes of ethanol and diesel oil offset in the electrostatic field were 2. 18 mm and 2. 69

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mm, respectively. Diesel oil density (0. 839X103 kg / m3) Specific to an ethanol density (0. 791X103kg/m3) Slightly larger, the diesel surface tension coefficient (26.8X10-3 N/m) is larger than that of ethanol (22.32X 10-3 N/m). According to equation (1), the diameter of diesel droplets formed is slightly larger than that of ethanol droplets.

4.2. Offset angle contrast

When the electric field voltage is low, the ethanol and diesel droplets only offset and fall off without breaking. The voltage drops shifts at 15 kV as shown in Figure 5. According to Figure 5, when the offset angle of ethanol and diesel droplets increases with the increase of voltage, the droplets are deformed but not broken.

The contrast curves of the offset angle changes of ethanol and diesel in the electrostatic field are shown in Figure 6. The theoretical offset angle of ethanol in the electrostatic field when the voltage is 1 kV.=4.29°, actual deviation angle 0=4.18°, deviation 0.11°; the theoretical deviation angle of diesel.=3. 72°, actual measured value 3 = 3. 56°, deviation is 0.16°; when the voltage is 5kV, the offset angle of ethanol and diesel is 21.21° and 17.86° respectively. The offset angle of both ethanol and diesel droplets increased with increasing voltage, but the offset angle of diesel is significantly smaller than that of ethanol, due to the different surface tension. From Equation (2), in the case of other parameters unchanged, the larger the surface tension, the smaller the offset angle.

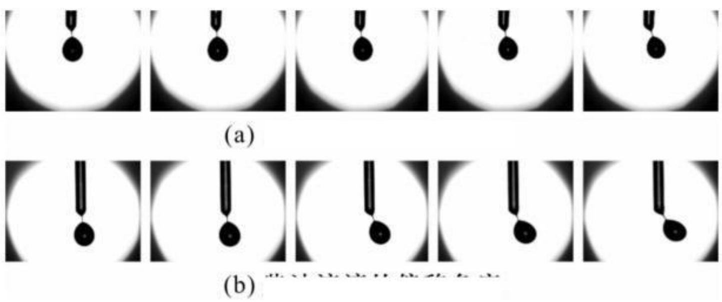

Figure 5 shows the offset angle of the droplet in the electrostatic field at the flow rate of 1.0ml / h

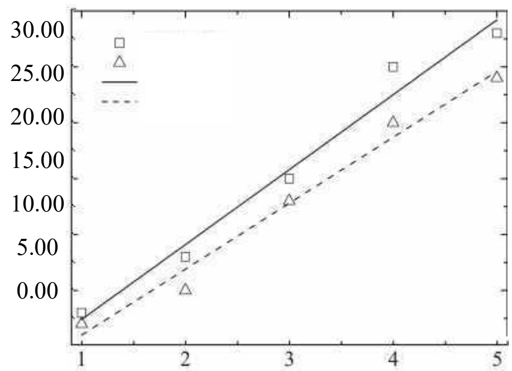

Figure 6 drop offset angle change in the electrostatic field at 1.0 ml / h

4.3. Comparison of broken average particle size

When the voltage rises, the droplet will be severely deformed and broken. However, if the flow rate is too low, only increasing the drive voltage will cause the end of the capillary occlusion and cannot form droplets. Therefore, when the liquid flow rate is adjusted to l 00 ml / h and the voltage is increased to 1722 kV, the pair of ethanol and diesel droplets are broken as shown in Figure 7. It can be seen that with the increase of voltage, the broken droplets has a few large particles and a lot of small particle droplets with uneven size distribution. When the diesel oil breaks, the particle size is more uniform than that of ethanol.

Statistics of mean particle size after broken ethanol and diesel droplets at a voltage of 1725 kV are shown in Figure 8. When the voltage is 17kV, the average crushing diameter of ethanol is 183 μ m, and

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the average crushing size of diesel is 198 μ m. When the voltage reaches 25 kV, the average crushing size of ethanol is 66, and the average crushing size of diesel is 71 μ m. It can be seen that both the particle size of ethanol and diesel crushing solution decreases, and the average crushing particle size of ethanol is always slightly less than the average crushing size of diesel oil. This is because the maximum charge of diesel is similar to that of ethanol, while the surface tension of diesel is greater than that of ethanol, so diesel is relatively stable.

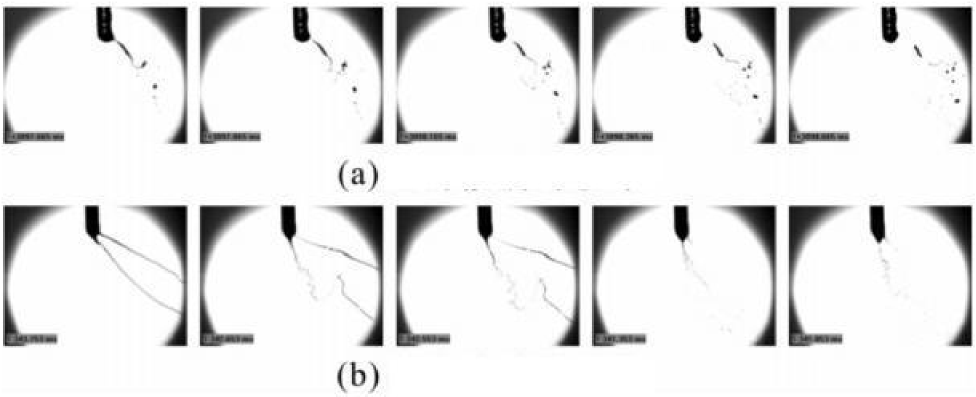

Figure 7 shows fragmentation in the droplet electrostatic field at a flow rate of 100 ml / h

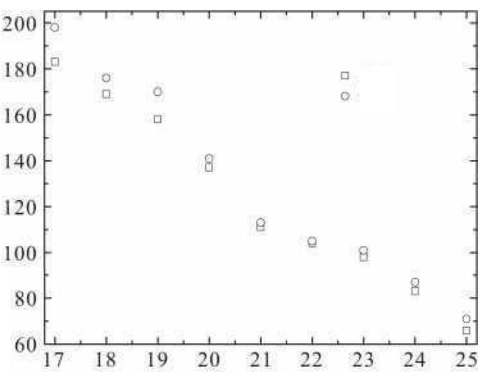

Figure 8 Change in average particle size of droplet fragmentation at a flow rate of 100 ml/h

5. Conclusion

Studying the shedding and crushing characteristics of ethanol and diesel droplets in the electrostatic field, we found that the droplet deviates and falls off, and the deviation angle increases with the voltage increase; at high electric field voltage and large flow rate, the average particle size of the crushing droplet decreases with the voltage increase; the surface tension decreases the value of the shedding and crushing.

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